The Ordovician–Silurian Boundary and its Working Group

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Synopsis

After a brief history of the study and definition of the Ordovician–Silurian boundary in the nineteenth and early twentieth centuries, the process of setting up the Ordovician–Silurian Boundary Working Group is described, together with its progress, publications and final decision-making during the period 1974–1985.

Both the Cambrian and the Silurian Systems were established as formal system names by Sedgwick and Murchison respectively amicably enough in 1835, but during the next thirty years it become clear that the upper part of Sedgwick's Cambrian occupied the same time and space as the lower part of Murchison's Silurian. It was not until after the deaths of both men that Charles Lapworth in 1879 established the Ordovician System to occupy the chief overlapping ground between the older part of the Silurian and the younger part of the Cambrian. In contrast to the rather generalized earlier definitions of the boundaries of the Cambrian and Silurian, Lapworth's definition of the limits of the Ordovician was admirably precise: he defined the new Ordovician System as the 'strata included between the base of the Lower Llandovery formation and that of the Lower Arenig' (Lapworth 1879: 14). There were subsequently problems (which are still not entirely resolved today) about the position and international correlation of the 'base of the Lower Arenig', but these are the province of the Cambro–Ordovician Boundary Working Group and will not be further discussed here. 'The base of the Lower Llandovery' has been much less ambiguous, and thus in general any dispute surrounding the definition of the Ordovician–Silurian boundary has always been of a much lesser magnitude than the problems of the Cambro–Ordovician and the Siluro–Devonian boundaries.

From the time of Murchison onward, 'the base of the Lower Llandovery' was defined primarily in terms of shelly facies and without much precision, and usually recognized by the incoming of various pentameride brachiopods such as *Stricklandia*. However, following Charles Lapworth's classic work on the Ordovician and Silurian rocks of Scotland in the period 1870 to 1880, it became clear that the best national and international correlation tool in rocks of those ages was the sequence of graptolite zones, and these zones were subsequently used in practice, with Lapworth himself, and subsequently the great graptolite monograph of Elles & Wood (1901–1918), using the *acuminatus* Zone (type locality Dob's Linn, Scotland) as the *de facto* base of the Silurian. The *acuminatus* Zone was poorly developed as such in Wales, and so Jones (1909) erected the *persculptus* Zone (type locality Pont Erwyd, Wales), which was subsequently realised to be of the same age as the lower part of Lapworth's broad *acuminatus* Zone in Scotland. Thereafter most stratigraphers treated the *persculptus* Zone as the base of the Silurian, e.g. in the *Lexique stratigraphique international* (Whittard 1961), and this horizon was also taken as the base of the Silurian by Cocks *et al.* (1970) when they erected stages for the Llandovery Series, with a basal boundary defined at Dob's Linn.

It was probably the identification of the problems surrounding the Silurian–Devonian boundary and their subsequent illumination and solution that gave impetus to the international effort and will to define properly the exact horizon and identify a type locality for the various systemic divisions of the Phanerozoic. The Siluro–Devonian Boundary Working Group worked formally between 1960 and 1972 (Martinsson 1977), but that work was preceded by a period of uncertainty, during which some of the procedures within the International Geological Congresses and the International Union of Geological Sciences were being developed.

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And so it was during the Ordovician–Silurian symposium at Brest, France, in 1971 that Claude Babin was the first to identify vocally the need for a group to be formally established to investigate and stabilize the Ordovician–Silurian boundary. This was put to the nascent Commission on Stratigraphy at the International Geological Congress in Montreal, Canada, in 1972, who felt that such a boundary working group should be established not by that commission directly, but at a suitable international meeting and through the joint coordination of the then proposed Ordovician and Silurian Subcommissions. These last two bodies were finally established at the Ordovician Symposium at Birmingham, England, in September 1974, and one of their first acts was to arrange the initial meeting of the Ordovician–Silurian Boundary Working Group, which first met at Birmingham on 19th September 1974. Those present at that meeting were C. Babin (France), C. R. Barnes (Canada), S. M. Bergström (USA), A. J. Boucot (USA), L. R. M. Cocks (UK), J. Destombes (Morocco), J. K. Ingham (UK), V. Jaanusson (Sweden), P. J. Lespérance (Canada), D. J. McLaren (Canada), L. Marek (Czechoslovakia), F. Martin (Belgium), R. B. Rickards (UK), P. Sartenaer (Belgium), N. Spjeldnaes (Denmark), L. Teller (Poland), J. T. Temple (UK) and E. A. Yolkin (USSR). It was decided that 6 voting members of the Working Group should be nominated by both the Ordovician and the Silurian Subcommissions, plus their two chairmen *ex officio*, and that 3 voting members from the USSR and 1 from Czechoslovakia should be nominated by their respective academies of science. Thus the Ordovician Subcommission nominated Barnes, Bergström, W. B. N. Berry (USA), Destombes, Ingham and Jaanusson, with A. Williams (UK) *ex officio* as their Chairman, and the Silurian Subcommission nominated Boucot, Cocks, S. Laufeld (Sweden), Lespérance, Rickards and Temple, with Spjeldnaes *ex officio* as their Chairman. Any interested and active worker on Ordovician–Silurian boundary problems could be accepted as a Corresponding Member. At that first meeting R. B. Rickards was elected by those present as the Chairman of the Working Group, and L. R. M. Cocks as the Secretary. It was also decided that most of the Group's activities and communication would take the form of circulars to be issued by the Secretary, and this is what subsequently happened, although field and discussion meetings also took place, and that the circulars should include reports on various Ordovician–Silurian sections or countries and also on the different fossil groups. The first circular was issued in October 1974: it reported the formation of the Working Group, and listed which members had promised to prepare reports.

In the next few years many circulars were issued, which included reports on boundary sections in Australia, Austria, Belgium, Canada (many areas), China, Czechoslovakia, England, France, Italy, Morocco, Poland, Scotland, Sweden, Wales, USA and USSR (Altai Mountains, East Baltic, Kazakhstan and NE Siberia), and also on acritarchs, chitinozoa, conodonts, graptolites and physical changes near the boundary. Many people became Corresponding Members, and the Voting Members were increased by D. L. Kaljo, T. N. Koren and I. F. Nikitin from the USSR, L. Marek from Czechoslovakia and Mu En-zhi from China, all of these nominations being accepted and ratified at the appropriate times by the I.U.G.S. Commission on Stratigraphy, the parent body of the Working Group. Meetings were held at the International Geological Congress at Sydney, Australia, in August 1976 and informal meetings at Alma-Ata, USSR, in May 1977 and at the Ordovician Symposium at Columbus, USA, in August 1977, and it became clear that a more substantial meeting of the Working Group would be valuable so that future plans of action could be formulated. This coincided with an expressed wish by various geologists to see the classic sections of Great Britain, and accordingly a meeting was arranged from 30th March to 11th April 1979, jointly with the Silurian Subcommission. By that time R. J. Ross jr and C. H. Holland had taken over the chairmanships of the Ordovician and Silurian Subcommissions respectively.

Those attending the British meeting in 1979 were (Voting Members of the Ordovician–Silurian Boundary Working Group with an asterisk): *C. R. Barnes (Canada), M. G. Bassett (UK), *L. R. M. Cocks (UK), *C. H. Holland (Ireland), *J. K. Ingham (UK), J. S. Jell (Australia), Jin Chun-tai (China), *D. L. Kaljo (USSR), P. Legrand (France), *P. J. Lespérance (Canada), Lin Bao-yu (China), F. Martin (Belgium), A. Martinsson (Sweden), *Mu En-zhi (China), *R. B. Rickards (UK), H.-P. Schönlaub (Austria), B. S. Sokolov (USSR), L. Teller

Fig. 1 The British field meeting, April 1979, outside Ludlow Castle, Shropshire. From left to right L. R. M. Cocks, Jin Chun-tai (obscured), B. D. Webby, C. R. Barnes, J. S. Jell, Wang Wei, Lin Bao-yu (obscured), D. Kaljo, Mu En-zhi, D. J. Siveter, F. Martin (obscured), L. Teller, P. J. Lespérance (obscured), D. E. White, A. Martinsson, B. S. Sokolov, P. Legrand, J. T. Temple, H. P. Schönlaub, M. G. Bassett, R. B. Rickards. (Photo C. H. Holland).

(Poland), *J. T. Temple (UK), G. B. Vai (Italy) and B. D. Webby (Australia). Thus more than half the Voting Members and a considerable breadth of both stratigraphical and palaeontological expertise were represented (Fig. 1). Sections were examined in Wales (Llandovery, Meifod, Hirnant and Pont Erwyd), the Lake District of England (Yewdale, Skelgill and Spengill), and Scotland (Dob's Linn), but, more importantly, business meetings were held in the evenings. Following a long-standing tradition of the Commission on Stratigraphy (whose then Chairman, Martinsson, and Secretary, Bassett, were present) all of the people present were allowed to participate freely in the discussions and also to take part in the informal voting which took place.

The various animal and plant groups were discussed and reviewed in turn, and it was agreed that only graptolites, brachiopods, conodonts, and to a lesser extent trilobites, were important in the Ordovician–Silurian boundary discussions in the present state of knowledge. Localities were then considered. Having inspected the type Llandovery area, all members present were unanimous in rejecting that area as the boundary stratotype, large due to the unfossiliferous nature of the A_1 Sandstone of Jones (1928) at the base of the succession, the sporadic exposure near the base, and the lack of stratigraphically critical fossils, particularly graptolites and conodonts, then known from beds near the boundary (although this situation has been much improved by subsequent work, Cocks *et al.* 1984). Other localities were graded in turn, with the following scheme: A, a possible section for placing the boundary; B, an important section which may be considered further in discussing the boundary, and C, a section or area unlikely to prove important in boundary definition. The grading was as follows:

A Anticosti Island (Canada), Dob's Linn (Scotland).
B Carnic Alps (Austria), Cornwallis Island (Canada), Hupei (China), Mirnyi Creek (Siberia,

USSR), Missouri (USA), Nevada (USA), Pont Erwyd (Wales), Szechuan (China) and Yewdale Beck (Lake District, England).

C Australia, Bala district (including Hirnant area, Wales), Belgium, Bohemia (Czechoslovakia), France, Garth (Wales), Hudson Platform (Canada), Kazakhstan (USSR), Kweichow (China), Lake District (apart from Yewdale Beck, England), Manitoba (Canada), Manitoulin Island (Canada), Morocco, Newfoundland (Canada), North American mid-continent (except Missouri and Nevada), Pembrokeshire (Wales), Percé (Canada), Poland, Scania (Sweden), Shensi (China) and Yukon (Canada).

In addition the Working Group then felt that more reports were needed from Algeria, Bornholm (Sweden), Burma, Dalarna and Västergötland (Sweden), Estonia (USSR), India and the Himalayas, Norway, Rae Grain (Scotland), Portugal, South America, Spain and West Nevada: however, although more data on some of these areas were subsequently gathered, none proved to have much extra to offer in the main definition of a stratotype. Because Anticosti Island, Canada, was one of the leading contenders for the definitive boundary section, it was agreed that a further field meeting should be held there. Other briefer meetings were also held in Paris, France, during the 1980 International Geological Congress, and in the Carnic Alps of Austria in late July and early August 1980. Meanwhile the debate persisted as to the best method of correlation across the boundary interval, and whether the actual boundary should be defined by the use of conodonts or graptolites. It was generally agreed that brachiopods and trilobites should not be used in the definition, except that there was a strong feeling that the widespread *Hirnantia* brachiopod fauna should be included within the Ordovician rather than the Silurian.

The Working Group circulars also contained various discussion and position papers between 1978 and 1982 on the theory and practice of defining the boundary both geographically and biostatigraphically. Opinions differed as to whether or not the stratotype could be satisfactorily placed within a nearly exclusively graptolite sequence such as Dob's Linn, and, if the boundary was to be defined on graptolites, whether it was to be at the base of the *extraordinarius*, the *persculptus* or the *acuminatus* Zone. There was no real consensus on the answers to these questions.

The field meeting to Quebec, which was partly in Anticosti Island and partly in the Gaspé Peninsula, was held in July 1981, again jointly with the Silurian Subcommission. Those attending (apart from various other Canadian hosts) were T. W. Amsden (USA), *C. R. Barnes (Canada), *A. J. Boucot (USA), *L. R. M. Cocks (UK), *C. H. Holland (Ireland), P. Legrand (France), *P. J. Lespérance (Canada), F. Martin (Belgium), G. M. Philip (Australia), *R. J. Ross jr (USA), H.-P. Schönlaub (Austria) and L. Teller (Poland). This was a rather disappointing attendance, particularly of Voting Members, and hence the evening discussion meetings were not as representative of the differing positions of the complete group as they might have been if the attendance had been better. A review was given of each of the relevant biological groups, and general discussions ensued, with the following points noted. There were very favourable general impressions of the simplicity of structure and good exposure at Anticosti, but reservations on the lack of graptolites there near the Ordovician–Silurian boundary and the relative lack of work done on groups other than conodonts on the beds near the boundary. Opinions differed about the accessibility of Anticosti Island and also about the importance of the structural complexity of the Dob's Linn area. At the end of the meeting, two straw votes indicated that those present thought that Anticosti was the best available section across the Ordovician–Silurian boundary in the shelly facies, and that, other things being equal, it would be preferable to have the Ordovocian–Silurian boundary stratotype in the same area as the stratotype area for the lowest series of the Silurian System. The latter point was relevant since at that time Anticosti was one of the three candidates under consideration by the Silurian Subcommission (the other two being Llandovery itself and the Oslo Region, Norway) for the stratotype for the lowest Silurian series. Shortly after this meeting, R. B. Rickards resigned as Chairman of the Working Group, and, because it was clear that the decisions on the boundary were close to being taken, the Commission on Stratigraphy subsequently appointed the Chairmen of the

Ordovician and Silurian Subcommissions, R. J. Ross jr and C. H. Holland, as Co-Chairmen of the Group; which they remained until its closure.

After the formal circulation of a number of further views on the position and correlation of the future boundary stratotype through the Circular, and informal discussion between interested people, it was agreed that maximum publicity and attendance should be sought for a meeting of the Working Group at the Ordovician Symposium at Oslo, Norway, so that progress would be made on the boundary decision. At that symposium, two meetings of the boundary Working Group were held, as well as seven papers on the boundary being presented within the normal symposium sessions. The meetings, on 20th and 23rd August 1982, attracted 53 and 76 people respectively, including the following Voting Members: Barnes, Bergström, Berry, Cocks, Destombes, Holland, Jaanusson, Kaljo, Lespérance, Rickards and Ross. After lengthy discussion, the first decision taken was whether or not the time was yet ripe for a formal vote on deciding the boundary stratotype and horizons, and, despite strong pleas for delays to enable more research to be done from several speakers, it was decided by 47 votes to 14 that the time had now come. The choice of stratotype boundary had been narrowed to three:

(i) the first appearance of the conodont *Ozarkodina oldhamensis* at 50 cms above the Oncolitic Platform Bed at Ellis Bay, Anticosti Island, Canada.
(ii) the base of the *persculptus* graptolite Zone at Dob's Linn, near Moffat, Scotland.
(iii) the base of the *acuminatus* graptolite Zone at Dob's Linn.

At the Oslo meeting two informal votes were then taken: (i) Anticosti was preferred to the *persculptus* Zone at Dob's Linn by 34 votes to 13, with 25 abstentions; (ii) Anticosti was preferred to the *acuminatus* Zone at Dob's Linn by 35 votes to 13, with 26 abstentions. The same questions were also informally voted upon by the 30 Voting and Corresponding Members of the Working Group who were present, and 17 preferred Anticosti against 7 for the *persculptus* Zone (6 abstentions); and 19 preferred Anticosti against 5 for the *acuminatus* Zone (6 abstentions). Therefore, it was clear that a substantial majority of those at the meeting then preferred to place the base of the Silurian at Anticosti Island using conodonts, and that the Voting Members of the Working Group should take part in a formal postal ballot in the light of this knowledge. Thus Circular No 17 was distributed to the members in October 1982 with a ballot paper to be returned by the end of January 1983. There followed a period during which various letters were informally circulated and lobbying took place, although none formally through the Secretary apart from a paper by P. Legrand which was very critical of the Oslo decision and which was distributed with Circular 17.

At the end of the formal voting period, the votes returned stood as follows:

(i) Which do you prefer—Anticosti or the *persculptus* Zone at Dob's Linn?
For Anticosti: Barnes, Bergström, Boucot, Holland, Lespérance, Ross: total 6.
For *persculptus* Zone: Berry, Cocks, Destombes, Ingham, Kaljo, Koren, Laufeld, Marek, Nikitin, Rickards, Temple: total 11.
No vote received: Jaanusson, Mu: total 2.
(ii) Which do you prefer—Anticosti or the *acuminatus* Zone at Dob's Linn?
The votes received were identical to the *persculptus* Zone vote.

These results were distributed to all members of the Working Group in Circular 18 in March 1983. Since there had been an outright majority on the selection of Dob's Linn rather than Anticosti, this was accepted by the officers as a decision, and a second formal postal vote was called for, firstly to give Voting Members an opportunity to change their minds, and secondly to decide between the *persculptus* and the *acuminatus* Zones at Dob's Linn for the stratotype horizon. Opportunity was also given to the Corresponding Members to formally express their opinions. The results of this second ballot was announced in Circular No. 19 in August 1983, and were as follows:

(i) the place of the stratotype.
Voting Members. Dob's Linn: Berry, Cocks, Destombes, Holland, Ingham, Kaljo, Koren,

Laufeld, Marek, Nikitin, Rickards, Temple: total 12. Anticosti: Barnes, Bergström, Boucot, Lespérance, Ross: total 5. Abstain: Jaanusson, Mu: total 2. In addition 14 Corresponding Members voted for Dob's Linn, 8 for Anticosti, and 4 abstained.

(ii) the horizon of the stratotype.

Voting Members. Base of *acuminatus* Zone: Cocks, Holland, Ingham, Jaanusson, Kaljo, Koren, Marek, Nikitin, Rickards, Temple: total 10. Base of *persculptus* Zone: Berry, Destombes, Laufeld, Mu, Ross: total 5. Abstain: Barnes, Bergström, Boucot, Lespérance: total 4. 13 Corresponding Members voted for the base of the *acuminatus* Zone, 9 for the base of the *persculptus* Zone, and 5 abstained.

In addition the question of possible parastratotypes was also voted upon, with the possibility of erecting one parastratotype on Anticosti Island and the other in China, but on this question only 8 Voting Members voted for the erection of these, with 3 against and 8 abstentions, and so the officers decided not to proceed further on that topic, and they were assisted in that decision by informal advice against parastratotypes from the Commission on Stratigraphy.

Thus since there was a clear majority for placing the Ordovician–Silurian stratotype boundary at the base of the *acuminatus* graptolite Zone at Dob's Linn, Scotland, this decision was formally forwarded to the Commission on Stratigraphy for consideration with various other matters at their meeting at the International Geological Congress at Moscow, USSR in August 1984. The decision was endorsed by a postal vote of that committee, who subsequently forwarded it to the I.U.G.S. for ratification. The proposals were reported to a meeting of the full I.U.G.S. Executive Committee in Rabat, Morocco, in February 1985 and submitted to the I.U.G.S. Executive for a postal ballot, whose result was declared in May 1985, and published in June 1985 (Bassett 1985), together with an article describing the Ordovician–Silurian boundary at Dob's Linn (Cocks 1985). The Ordovician–Silurian Boundary Working Group was finally dissolved in its Circular No. 20, distributed in June 1985.

The life of the Ordovician–Silurian Boundary Working Group was therefore somewhat over ten years long, but it was useful not only in determining the position and horizon of the boundary itself, but also in stimulating a great deal of research in various parts of the world, and in encouraging international understanding and cooperation.

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Appendix

MEMBERSHIP OF THE ORDOVICIAN–SILURIAN BOUNDARY WORKING GROUP

Those names with an asterisk* were Voting Members, the remainder were Corresponding Members.

Amsden, T. W.	USA
Apollonov, M. K.	USSR
Babin, C.	France
*Barnes, C. R.	Canada
Bassett, M. G.	UK
Bergström, J.	Sweden
*Bergström, S.	USA
*Berry, W. B. N.	USA
Bolton, T. E.	Canada
*Boucot, A. J.	USA
Brenchley, P. J.	UK
Bruton, D. L.	Norway
*Cocks, L. R. M.	UK
Cramer, F. H.	Spain
*Destombes, J.	Morocco
Hamada, T.	Japan
*Holland, C. H.	Ireland
*Ingham, J. K.	UK
*Jaanusson, V.	Sweden
Jackson, D. E.	UK
Jaeger, H.	East Germany
Jin Chun-tai	China
*Kaljo, D.	USSR
Kobayashi, T.	Japan
*Koren, T. N.	USSR
*Laufeld, S.	Sweden
Legrand, P.	France
Lenz, A. C.	Canada
*Lespérance, P. J.	Canada
Lin Bao-yu	China
*Marek, L.	Czechoslovakia
Martin, F.	Belgium
Martinsson, A.	Sweden
McLaren, D. J.	Canada
*Mu En-zhi	China
*Nikitin, I. F.	USSR
Norford, B. S.	Canada
Nowlan, G. S.	Canada
Oradovskaya, M. M.	USSR
Poulsen, V.	Denmark
*Rickards, R. B.	UK
Rong Jia-yu	China
*Ross, R. J. jr	USA
Sartenaer, P. J. M. J.	Belgium
Schönlaub, H. P.	Austria
Sheehan, P. M.	USA
Sokolov, B. S.	USSR
Spjeldnaes, N.	Denmark
Teller, L.	Poland
*Temple, J. T.	UK
Toghill, P.	UK
Wang Xiao-feng	China
Webby, B. D.	Australia
Williams, A.	UK
Williams, S. H.	UK
Wright, A. D.	UK
Yolkin, E. A.	USSR